ABSTRACT

In an investigation of plant microfossils from the Raritan Formation of New Jersey, U. S. A., two new genera and thirty-six new species are described. The climate during Raritan time ranged from subtropical to temperate. The age of the Raritan Formation is considered to be the earliest Late Cretaceaus. The presence of marine microfossils suggests a shallow-water marine environment for this formation.

New plant microfossils from the Raritan Formation (Cretaceous) in New Jersey

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INTRODUCTION

A palynological investigation of the Raritan Formation in New Jersey was undertaken with the following objectives: 1) to identify the previously described microfossils and describe any new taxa which might be encountered, 2) to establish the botanical affinities of the described taxa wherever possible, 3) to interpret paleoecological factors reflected by the flora, 4) to attempt to determine geologic age by the use of palynological analysis, and 5) to compare microfossils recovered from the Raritan Formation with those of similar contemporaneous floras.

The collected samples and microscope slides are stored in the Oklahoma Palynological Collection (OPC) of the Oklahoma Geological Survey, Norman, Oklahoma.

The writer wishes to express his gratitude to Dr. L. R. Wilson, who supervised the research of this investigation and provided facilities for this study. Appreciation is also expressed to Dr. C. Branson, who provided facilities for this research at the Oklahoma Geological Survey.

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STRATIGRAPHY

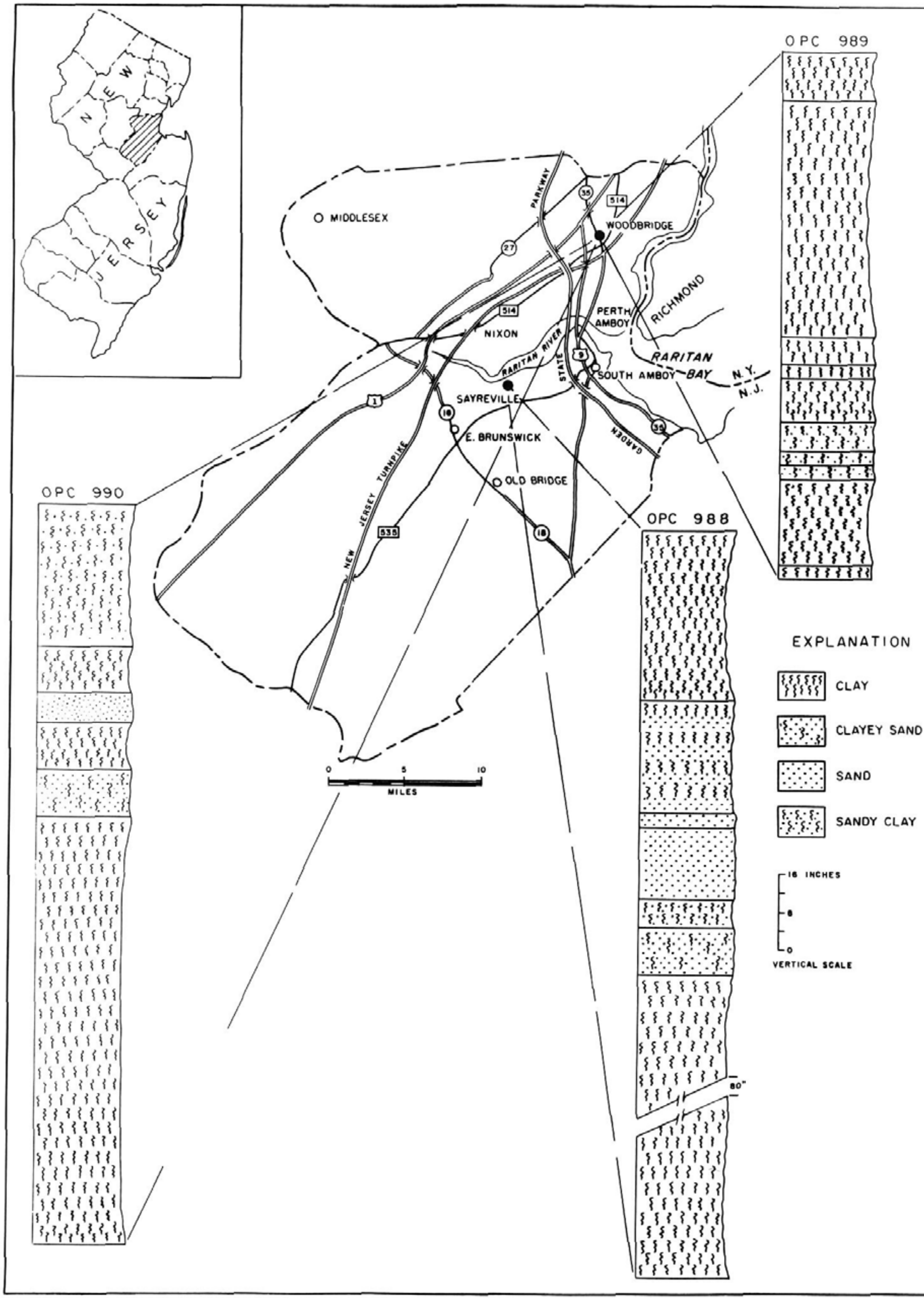
The Atlantic Coastal Plain extends from the present coast inland to the exposed area of the Triassic rocks. It is composed of unconsolidated sediments which range in age from Cretaceous to Recent.

The sediments of this area in New Jersey consist of sands, clays, beds of glauconite, limestones, and calcareous sands. The Upper Cretaceous deposits in New Jersey have been divided by earlier workers into the following eleven formations: Raritan, Magothy, Merchantville, Woodbury, Englishtown, Marshalltown, Wenonah, Mount Laurel, Navesink, Red Bank, and Tinton.

In this area the oldest division of the Cretaceous is the Raritan. The name Raritan was proposed as a formational name by Clark (1893) to replace "Plastic Clay", a lithologic name. The lithologic character of the formation is described by Kümmel and Knapp (1904). For the most part the Raritan Formation is made up of alternating beds of clays and sands with local lignitic sediments and gravels.

In an early report (Kümmel and Knapp, 1904), the Raritan Formation was divided into seven "beds": Raritan Fire and Terracotta (Potter's) Clay, Fire Sand No. 1, Woodbridge Clay, Feldspar-Kaolin Sand No. 2, South Amboy Fire Clay, Sand Bed No. 3, and Amboy Stoneware Clay. Although these divisions may be seen in many outcrops, they can not be followed any great distance. Near Woodbridge and Sayreville, New Jersey, the Raritan Formation consists of white clay which weathers red and grades laterally and vertically into dark-grey lignitic clay. The base of this dark clay is not exposed, but it is believed to be the bottom of the Woodbridge Clay Member. At Sayreville the upper portions of the Woodbridge Clay Member of the Raritan Formation contain impure siderite nodules.

Abundant animal megafossils and microfossils have been collected and described from the Raritan Formation of New Jersey. The flora of the formation was originally described by Newberry (1895). Berry (1911) made additional collections and studied both the fossil plants and the stratigraphy of the formation. According to Kümmel and Knapp (1904), the sands and clays of the Raritan Formation were generally considered to have accumulated under broad estuarine conditions. The few invertebrate fossils known from the formation at that time were believed to have lived in brackish waters.



TEXT-FIGURE 1

Location map and sampled columnar sections in the Raritan Formation of Middlesex County, New Jersey.

The fauna described by Stephenson (1954) and collected in a clay pit of the Sayre and Fisher Brick Company contained a new genus, nine new species and one new subspecies, and definitely belonged to a group of organisms which inhabited shallow marine water. Therefore, it appears that shallow marine conditions existed while at least part of the Raritan Formation was being deposited.

SAMPLED SECTIONS

Three sections of the Woodbridge Clay Member of the Raritan Formation were measured and sampled. These are located in Sayreville and Woodbridge, New Jersey. Sampled sections and their localities are shown in text-figure 1. Samples taken from the above sections are arranged in stratigraphic order and labeled A, B, C, *etc.*, from the base upward.

1) OPC 988 – Pit No. 4 of the Sayre and Fisher Brick Company, on Main Street at River Road, Sayreville, New Jersey. The thickness of the section is 238 inches, and 15 samples were collected.

2)OPC 989 – Clay pit of the Valentine Fire Brick Company, on Main Street, ½ mile from Amboy Avenue, Woodbridge, New Jersey. The thickness of the section is 111 inches, and 23 samples were collected.

3) OPC 990 – Clay pit of the Valentine Fire Brick Company, on Florida Grove Road, Woodbridge, New Jersey. The thickness of the section is 156 inches, and 15 samples were collected.

SAMPLE PREPARATION AND STUDY

With little variation, the laboratory techniques used were those outlined by Wilson (1959*a*). Each sample was finely crushed and covered with hydrochloric acid for 24 hours. The material was washed, treated with hydrofluoric acid, boiled 20–30 minutes, immediately diluted with cold water, and permitted to settle for 24 hours. The material was washed, then covered with Schultz's solution, and allowed to stand for 24 hours. Residues were again washed and treated with potassium hydroxide for 15–20 minutes. Then the material was washed, stained with safranin and mounted in Clearcol (Wilson, 1959*b*). Ten slides were made from each sample. For designation, each specimen has been given a sample number, slide number and ring number.

DISCUSSION OF THE MICROFLORA

The palynological investigation of three sections of the Raritan Formation in New Jersey yielded 53 genera containing 87 species. Of the total assemblage, 2 genera and 36 species are considered new. The new forms are assigned binominal names and described in this paper. Fossil preservation in the Raritan sediments is fair to excellent.

The following list is the phylogenetic grouping of the species of spores and pollen found in the Raritan Formation of New Jersey. The dominant species are designated by an asterisk.

Bryophyta

Sphagnaceae
- * *Sphagnumsporites* sp. cf. *S. australis* (Cookson, 1947) Potonié (1956)
- * *Sphagnumsporites psilatus* (Ross, 1949) Couper (1958)
- *Sphagnumsporites clavus* (Balme, 1957), n. comb.

Pteridophyta

Lycopodiaceae
- * *Lycopodiumsporites clavatoides* Couper (1958)
- * *Lycopodiumsporites cerniidites* (Ross, 1953) Delcourt and Sprumont (1955)
- *Lycopodiacidites baculatus* Pocock (1962)
- * *Camarozonosporites rudis* (Leschik, 1955) Klaus (1960)
- *Cingulatisporites problematicus* Couper (1958)
- *Cingulatisporites carinatus*, n. sp.
- *Cingulatisporites exiniconfertus*, n. sp.
- *Cingulatisporites pyriformis*, n. sp.

Osmundaceae
- * *Osmundacidites* sp. cf. *O. wellmanii* Couper (1953)
- *Todisporites minor* Couper (1958)
- *Todisporites major* Couper (1958)

Schizaeaceae
- * *Appendicisporites tricornitatus* Weyland and Greifeld (1953)
- *Appendicisporites* sp. cf. *A. ethmos* Delcourt and Sprumont (1959)
- *Appendicisporites multicornutus*, n. sp.
- *Cicatricosisporites striosporites* (Rouse, 1962), n. comb.
- * *Cicatricosisporites intersectus* Rouse (1962)
- * *Cicatricosisporites verrucosus*, n. sp.
- * *Cicatricosisporites goeppertii* (Seward, 1913) Groot and Penny (1960)
- *Klukisporites variegatus* Couper (1958)

Gleicheniaceae
- * *Gleicheniidites senonicus* Ross (1949)
- * *Gleicheniidites raritanianus*, n. sp.
- *Gleicheniidites orientalis* (Bolkhovitina, 1953), n. comb.

Cyatheaceae
- * *Cyathidites australis* Couper (1953)
- * *Cyathidites minor* Couper (1953)

Matoniaceae
- *Matonisporites globosus*, n. sp.

Cheiropleuriaceae?
- * *Dictyophyllidites harrisii* Couper (1958)

Sporae incertae sedis
- *Concavisporites granulatus*, n. sp.
- *Concavisporites tricornutus*, n. sp.
- * *Concavisporites orbicornutus*, n. sp.
- *Deltoidospora incomposita*, n. sp.
- *Aequitriradites insolitus*, n. sp.

Aequitriradites spinulosus (Cookson and Dettmann, 1958) Cookson and Dettmann (1961)
Pilosisporites papilloides, n. sp.
* *Rouseisporites laevigatus* Pocock (1962)
Densoisporites perinatus Couper (1958)
Wilsonisporites woodbridgei, n. sp.
Trachytriletes sp. cf. *T. ancoraeformis* Bolkhovitina (1953)
Discisporites discoides, n. sp.
* *Triletes* sp.
Balmeisporites holodictyus Cookson and Dettmann (1958)
Balmeisporites glenelgensis Cookson and Dettmann (1958)
Arcellites mirabilis, n. sp.
Arcellites nudus (Cookson and Dettmann, 1958) Potter (1963)
Arcellites caudatus, n. sp.

Gymnospermae

Cycadales-Bennettitales
Cycadopites sp. cf. *C. folicularis* Wilson and Webster (1946)
* *Monosulcites scaber*, n. sp.

Coniferales

Pinaceae
* *Abietineaepollenites microsaccus* Groot and Groot (1962)
* *Abietineaepollenites aequalis* Groot and Groot (1962)
* *Abietineaepollenites* sp. cf. *A. microalatus* Potonié (1931)
* *Abietineaepollenites microreticulatus* Groot and Penny (1960)
* *Pinuspollenites granulatus*, n. sp.
* *Pinuspollenites megasaccus*, n. sp.
* *Alisporites* sp. cf. *A. thomasii* (Couper, 1958) Pocock (1962)
* *Piceaepollenites subconcinnus*, n. sp.
* *Piceaepollenites alatus* Potonié (1931)
Tsugaepollenites insuetus, n. sp.
Parvisaccites sphaericorpus, n. sp.

Podocarpaceae
Podocarpidites ellipticus Cookson (1957)
* *Rugubivesiculites multiplex* Pierce (1961)
Dacrycarpites dacrydioides (Couper, 1960), n. comb.
Platysaccus radiatus, n. sp.
Chasmatosporites rimatus Nilsson (1958)

Taxaceae-Cupressaceae
Inaperturopollenites sp. cf. *I. atlanticus* Groot, Penny and Groot (1961)
* *Inaperturopollenites tenuis*, n. sp.

Araucariaceae
* *Araucariacites australis* Cookson (1947)

Coniferales incertae sedis
* *Naviculaformipites psilatus*, n. gen. and sp.
Naviculaformipites atlanticus, n. gen. and sp.

Pollen incertae sedis
Clavatipollenites hughesii Couper (1958)
* *Clavatipollenites couperi* Pocock (1962)
Schizosporis reticulatus Cookson and Dettmann (1959)
* *Schizosporis parvus* Cookson and Dettmann (1959)

Angiospermae

Palmae
* *Sabalpollenites, dividuus*, n. sp.

Proteaceae
Proteacidites rectilatus, n. sp.

Ulmaceae
Ulmipollenites sp. cf. *U. undulosus* Wolf (1934)

Dicotyledones incertae sedis
Conclavipollis densilatus, n. sp.
Tricolpites heusseri, n. sp.
* *Tricolpites* sp. cf. *T. reticulatus* Cookson (1947)
* *Tricolpites balmei*, n. sp.
* *Tricolpites wilsonii*, n. sp.

Marine microfossils
Hystrichosphaeridium raritanianum, n. sp.
Hystrichosphaeridium sp. cf. *H. armatum* Deflandre (1937)
* *Hystrichosphaeridium multicornutum*, n. sp.
Gonyaulax sp. cf. *G. pachyderma* Deflandre (1938)
Gonyaulax sp. cf. *G. wetzeli* Lejeune-Carpentier (1939)
Oodnadattia cooksonii, n. sp.

Comparison of the plant microfossils from the Raritan Formation with the Raritan plant megafossils shows that the ferns are the most abundant fossils in the palynological assemblage, while the angiosperms have the highest percentage among plant megafossils.

The main causes for the variance in the two floral assemblages are probably the following:

1) The megafossils are nomenclatorially based on several detached parts of plants, such as seeds, cones, woods, and sterile shoots, which exceed the true number of species.

2) The polymorphic nature of leaves (a simple leaf may be part of a compound leaf) increases the number of megafossil species.

3) Pollen grains of many plants are not identifiable to the species level. Statistical analysis has been used to recognize the different species of these grains.

4) Overrepresentation of spores and underrepresentation of pollen due to differential production and preservation.

PALEOECOLOGICAL INTERPRETATION

Although the ecological requirements for species and genera might have been somewhat different in the past, it is still possible to postulate the ecological conditions of Raritan time from the ecological study of modern groups to which the microfossils are related. In the following list the ecology of major groups represented in the palynological assemblage is discussed.

1) Bryophyta are represented in the formation by *Sphagnumsporites*, which is indicative of acid swamp conditions.

2) The Lycopodiaceae are abundant in the tropics but extend to the arctic.

3) The Osmundaceae are mainly tropical but extend also into subtropical and temperate areas.

4) The Gleicheniaceae are composed mainly of terrestrial ferns inhabiting the drier regions of the tropics and subtropics, but also the moist temperate areas of the Southern Hemisphere.

5) The Cyatheaceae, which are considered to be true tree ferns, are mostly found in tropical mountain forests but also exist in temperate regions.

6) The Schizaeaceae are mainly tropical but extend to the subtropical and temperate regions, and have world-wide distribution.

7) The Cycadaceae are mainly tropical to subtropical.

8) Bisaccate pollen grains related to those of Coniferales are abundant in the palynological assemblage. These are likely to have been derived from a regional upland in proximity to the deposition site.

9) The Podocarpaceae, consisting of the genera *Dacrydium* and *Podocarpus*, are mainly distributed in temperate regions.

10) Pinaceae are mainly in temperate regions of the Northern Hemisphere and extend from subarctic to subtropical regions. *Picea* indicates mainly cool temperate regions.

11) The Taxaceae and Cupressaceae, which are represented in the palynological assemblage by *Inaperturopollenites*, are mainly indicative of temperate climate and extend to warm temperate regions. Several modern species of these families live in shallow-water and swamp environments.

12) The Palmae, represented by *Sabalpollenites*, are generally tropical and subtropical.

13) Monosulcate pollen grains morphologically similar to the pollen grains of the modern genus *Ginkgo* had world-wide distribution during Mesozoic and Tertiary time, but today are found only in warm temperate regions.

14) Dicotyledonous angiosperms occur in a variety of habitats from arctic to tropical regions.

In general, palynological fossils recovered from the Raritan Formation indicate a subtropical to temperate climate. Marine microfossils such as *Hystrichosphaeridium* and *Gonyaulax*, which occur at most levels, suggest a shallow-water marine environment for the Raritan sediments in New Jersey. The writer has personally observed that marine microfossils are absent from the Raritan Formation of Long Island. This suggests that there was no marine invasion during Raritan time in the Long Island area.

AGE OF THE RARITAN FORMATION

The age of the Raritan Formation has been considered to be Early Cretaceous by some and Late Cretaceous by others. Newberry (in Berry, 1911) recognized the Amboy Clay as Cenomanian in age and correlated it with the Dakota Group of the West. Ward (in Berry, 1911) pointed out that the Raritan Formation was older than the Dakota Group and regarded the Raritan Formation as corresponding to the Albian of continental Europe. Berry (1911), in his description of the flora from Raritan sediments in New Jersey, considered the Raritan Cenomanian in age.

Richards (1943) and Stephenson (1954) described a marine fauna collected from the upper part of the Woodbridge Clay Member of the Raritan Formation and regarded it as basal Upper Cretaceous (Cenomanian).

Disagreement came from Spangler and Peterson (1950), who correlated the Raritan Formation of New Jersey with the combined Potomac Group and Raritan Formation of Maryland-Delaware.

Dorf (1952), in a review of the Cretaceous paleobotany and stratigraphy of the Atlantic Coastal Plain, regarded the Raritan Formation as lowermost Upper Cretaceous (Cenomanian). Groot, Penny and Groot (1961), in studying plant microfossils from the Raritan, Tuscaloosa and Magothy Formations of the eastern United States, concluded that the lower part of the Raritan (Raritan Fire Clay and Woodbridge Clay) is probably Cenomanian and the upper part of the Raritan deposits (South Amboy Fire Clay) is probably Turonian.

Palynological assemblages recovered from the Raritan Formation in this investigation also suggest earliest Late Cretaceous age. *Balmeisporites holodictyus* and *B. glenelgensis*, recorded from the Upper Cretaceous of Australia (Cookson and Dettmann, 1958), and *Arcellites*, recorded from the Upper Cretaceous of Disko Island, Greenland (Miner, 1935), the Upper Cretaceous of Iowa, Grill Coal (Schemel, 1950), and the Upper Cretaceous of Australia (Cookson and Dettmann, 1958), are all found in the Raritan sediments and indicate a probable Late Cretaceous age for the Raritan Formation.

Trilobosporites apiverrucatus Couper, which is reported to be a common form in the Potomac Group (Lower Cretaceous) by Groot and Penny (1960) and Brenner

(1963), is entirely absent from the Raritan Formation. On the other hand, if the angiosperms are considered as a relative age determinant in the Upper Cretaceous, the Raritan Formation, which contains small and mostly tricolpate forms, should be assigned to the basal Upper Cretaceous. The Magothy Formation, with mostly advanced triporate angiospermous pollen (writer's personal observation), should probably be called Turonian or younger in age.

SUMMARY AND CONCLUSIONS

In an investigation of spores and pollen from the Raritan Formation of New Jersey, an assemblage of 87 species included in 53 genera is reported. Of this total, 2 genera and 36 species are considered new.

The following conclusions and results are drawn from this palynological study:

1) The palynological assemblage includes species found in both the Lower and Upper Cretaceous. However, species reported from the Jurassic and Tertiary have also been observed.

2) No major floral changes were observed in the Raritan Formation. The vertical variation of the abundance and occurrence of species cannot be considered as a major floral change. This minor deviation is probably related to the alternating sands and clays within the formation.

3) Marine organisms are reported from all three sections of the Raritan in New Jersey.

4) The relative abundance of spores and pollen accompanying the marine microfossils suggests a shallow-water marine environment for the Raritan Formation in New Jersey.

5) The stratigraphic distribution and relative abundance of the species indicate that the ferns and gymnosperms comprise the dominant plant groups in the Raritan Formation. The angiosperms present at most levels are abundant in the upper part of the formation.

6) Among the ferns, *Lycopodiumsporites cerniidites*, *Camarozonosporites rudis*, *Gleicheniidites senonicus*, *Cyathidites minor* and schizaeaceous trilete spores are the dominant types. The gymnospermous pollen belongs chiefly to the families Pinaceae, Podocarpaceae, Araucariaceae, Taxaceae and Cupressaceae. The angiospermous pollen grains are mainly of the tricolpate type. A few tricolporate and triporate pollen grains have also been observed.

7) The climatic conditions during Raritan time probably ranged from subtropical to temperate.

8) The age of the Raritan Formation is considered to be earliest Late Cretaceous (Cenomanian). This determination supports the interpretation of Dorf (1952), based on megafossils, and that of Groot, Penny and Groot (1961), based on their analysis of microfossils.

SYSTEMATIC DESCRIPTIONS

Family Lycopodiaceae
Genus Cingulatisporites Thomson (1953)

Cingulatisporites carinatus Kimyai, new species
Plate 1, figure 1

Description: Trilete spore; laesurae short, extending more than half of radius of spore; commissures raised, surrounded by margo; exine smooth and thick, thinning at apices, 2–3 μ thick; equatorial flange 2.5–3.5 μ wide; equatorial contour triangular with convex sides; two cingula, triangular with very sharp corners, parallel to equator. Equatorial diameter 47–56 μ.

Holotype: OPC 990 G-3-5. Equatorial diameter 50.0 μ.

Remarks: This species is characterized by two parallel and triangular cingula, a heavy exine which becomes thinner at the corners, and a wide equatorial flange.

Affinity: Not known below family level.

Cingulatisporites exiniconfertus Kimyai, new species
Plate 1, figure 2

Description: Trilete spore; laesurae reaching inner margin of cingulum; commissures raised and surrounded by thick margo; equatorial contour in polar view rounded triangular, with convex sides and well-rounded apices; cingulum 0.5–1.5 μ wide; exine smooth, 2–3 μ thick. Equatorial diameter 25–32 μ.

Holotype: OPC 990 C-2-17. Equatorial diameter 27.0 μ.

Remarks: This species is represented by a few specimens in the Raritan Formation. A fairly similar form was described by Brenner (1963) from the Potomac Group of Maryland as *Cingulatisporites* sp.

Affinity: Not known below family level.

Cingulatisporites pyriformis Kimyai, new species
Plate 1, figure 3

Description: Trilete spore; laesurae long, extending to cingulum; commissures raised, flanked by margo, slightly narrowing toward cingulum; equatorial contour rounded triangular with almost straight sides and rounded corners; cingulum thin, 0.5 μ wide; exine smooth, thick at the corners, 1.5–2.5 μ thick. Equatorial diameter 40–51 μ.

Holotype: OPC 989 F-4-3. Equatorial diameter 40.0 μ.

Remarks: Only a few specimens have been found in the Raritan Formation.

Affinity: Not known below family level.

Family Schizaeaceae
Genus Appendicisporites Weyland and Krieger (1953)

Appendicisporites multicornutus Kimyai, new species
Plate 1, figure 4

Description: Trilete spore; laesurae distinct, extending to full radius of spore; equatorial contour triangular to ovate; sides convex; apices terminating in 2 or more projections 15–17 μ long; distal surface sculptured with ridges extending beyond the margin to the apices; ridges 2–4 μ wide, separated by furrows 1–2 μ wide. Equatorial diameter 63–71 μ.

Holotype: OPC 990 C-5-5. Equatorial diameter 67.0 μ.

Remarks: This species is characterized by more than two long projections in each corner. It is a rare form in the Raritan Formation.

Affinity: With spores produced by ferns of the family Schizaeaceae, genus *Anemia*; probably spores of *Anemia glareosa*.

Genus Cicatricosisporites Potonié and Gelletich (1933)

Cicatricosisporites verrucosus Kimyai, new species
Plate 1, figures 5–6

Description: Trilete spore; laesurae reaching to the equator, often showing gape at proximal end; commissures raised; equatorial contour rounded triangular; sides slightly or strongly concave; wall thickening at apices to 8–9 μ, thinning at sides to 2–3.5 μ; both proximal and distal sides ornamented with irregularly raised ribs 1–5 μ wide; interrib areas 2–6 μ wide. Equatorial diameter 50–67 μ.

Holotype: OPC 990 H-2-1. Equatorial diameter 50.0 μ.

Affinity: With spores produced by ferns of the family Schizaeaceae, probably with those of the modern genus *Anemia*.

Family Gleicheniaceae
Genus Gleicheniidites (Ross, 1949) Delcourt and Sprumont (1955)

Gleicheniidites raritanianus Kimyai, new species
Plate 1, figure 7

Description: Trilete spore; laesurae extending to the equator; commissures raised; equatorial contour triangular; sides straight or slightly concave; corners abruptly acute; exine reticulate, 1–1.5 μ thick at corners and up to 7 μ on sides. Equatorial diameter 26–37 μ.

Holotype: OPC 990 G-2-8. Equatorial diameter 30.0 μ.

Remarks: This species is characterized by acute corners and dentate equatorial thickening.

Affinity: With spores of ferns belonging to the family Gleicheniaceae.

Family Matoniaceae
Genus Matonisporites Couper (1958)

Matonisporites globosus Kimyai, new species
Plate 1, figure 9

Description: Trilete spore; laesurae about 3/4 of radius of spore; commissures raised and flanked by a distinct margo; equatorial contour rounded triangular; exine smooth, 2–2.5 μ thick. Equatorial diameter 52–63 μ.

Holotype: OPC 990 C-1-2. Equatorial diameter 55.0 μ.

Remarks: Matonisporites globosus differs from *Matonisporites equiexinus* Couper by its more rounded outline and thinner exine. In this form the laesurae do not extend to the equator. It is a common species in the Raritan Formation.

Affinity: With spores of ferns belonging to the family Matoniaceae.

Sporae incertae sedis
Genus Concavisporites Pflug (1953)

Concavisporites granulatus Kimyai, new species
Plate 1, figure 10

Description: Trilete spore; laesurae about 2/3 of radius of spore, distinct; commissures raised; equatorial contour triangular; sides straight distally and concave proximally; both proximal and distal sides sculptured with granules; exine 3–3.5 μ thick at apices, thickening on sides to 4–6 μ. Equatorial diameter 33–40 μ.

Holotype: OPC 990 A-4-1. Equatorial diameter 35.0 μ.

Affinity: Not known, but possible affinity with spores of genus *Dicksonia*, family Dicksoniaceae.

Concavisporites tricornutus Kimyai, new species
Plate 1, figure 11

Description: Trilete spore; laesurae indistinct, extending to equator; equatorial contour triangular, sides straight or slightly concave, corners terminating in auriculae; proximal sides ornamented by three broad and concave thickenings, parallel to the sides, joining at the apices to the ends of the laesurae; exine smooth, 2–2.5 μ thick Equatorial diameter 39–50 μ.

Holotype: OPC 989 F-5-5. Equatorial diameter 44.0 μ.

Affinity: Not known, but probably with spores of the family Gleicheniaceae.

Concavisporites orbicornutus Kimyai, new species
Plate 1, figure 12

Description: Trilete spore; laesurae extending to equator; commissures raised and surrounded by a weakly developed margo; equatorial contour triangular with strongly concave sides and rounded corners; exine psilate, in some forms scabrate, 3.5–5.5 μ thick. Equatorial diameter 48–55 μ.

Holotype: OPC 989 J–1–3. Equatorial diameter 52.0 μ.

Affinity: Not known..

Genus Deltoidospora Miner (1935)

Deltoidospora incomposita Kimyai, new species
Plate 1, figure 13

Description: Trilete spore; laesurae reaching to equator; commissures raised; equatorial contour rounded triangular with straight, concave or slightly concave sides and rounded corners; apices contain special ridges which may be connected to each other in some specimens; exine somewhat verrucate, 1–1.5 μ thick. Equatorial diameter 23–30 μ.

Holotype: OPC 990 J–5–5. Equatorial diameter 25.0 μ.

Remarks: This species appears to be similar to *Leiotriletes harpeformis* Bolkhovitina (1953) from Russia, except for its smaller size. It is rare in the Raritan Formation.

Affinity: Not known, but possibly with spores of the genera *Cladophlebis* and *Coniopteris.*

Genus Aequitriradites Delcourt and Sprumont (1955), emend. Cookson and Dettmann (1961)

Aequitriradites insolitus Kimyai, new species
Plate 1, figure 14

Description: Trilete spore; equatorial contour rounded triangular; laesurae long, reaching to equator and extending into membrane; exine slightly scabrate, 1 μ thick; spore body encircled by a thick equatorial membrane 5 μ wide. Equatorial diameter 37–56 μ.

Holotype: OPC 989 P–1–1. Equatorial diameter 40.0 μ.

Remarks: This species is characterized by a scabrate exine and a regular rounded triangular outline. It is rare in the Raritan Formation.

Affinity: Not known.

Genus Pilosisporites Delcourt and Sprumont (1955)

Pilosisporites papilloides Kimyai, new species
Plate 1, figure 15

Description: Trilete spore; laesurae reaching to equator, surrounded by margo; equatorial contour triangular with convex sides and rounded corners; surface ornamented with clear thick papillae rising 1–2 μ high from general level; exine fairly thick, 2–3 μ. Equatorial diameter 33–41 μ.

Holotype: OPC 989 F–3–2. Equatorial diameter 37.0 μ.

Remarks: This species differs from the others by having short and thick papillae. It is similar to species of *Concavisporites* but possesses spines. It is rare in the Raritan Formation.

Affinity: Not known.

Genus Discisporites Leschik (1955)

Discisporites discoides Kimyai, new species
Plate 1, figure 16

Description: Trilete spore; cingulate; equatorial contour circular; laesurae indistinct; exine 4–5 μ thick, very finely scabrate; polar region thick and opaque. Equatorial diameter 48–50 μ.

Holotype: OPC 990 L–4–5. Equatorial diameter 50.0 μ.

Affinity: Not known.

Genus **Wilsonisporites** Kimyai, new genus

Diagnosis: Trilete spore; laesurae extending to equator; commissures raised; equatorial contour triangular with sharp apices and straight or convex sides; sides bordered by a broad membrane; cingulum papillate with rays extending from the papillae into the membrane; exine with two layers, ectexine and endexine.

Type species: Wilsonisporites woodbridgei Kimyai, n. sp.

Wilsonisporites woodbridgei Kimyai, new species
Plate 1, figures 17–18

Description: Trilete spore; laesurae long, reaching to equator; commissures raised; equatorial contour with sharp apices and straight or convex sides, sides bordered by a broad membrane 3–7 μ wide; cingulum papillate with rays extending from the papillae into the membrane; exine 1–2 μ thick, containing two distinct layers. Equatorial diameter 38–53 μ.

Holotype: OPC 990 C–4–6. Equatorial diameter 43.0 μ.

Remarks: This species is characterized by a papillate cingulum and a membrane encircling the spore. It is rare in the Raritan Formation.

Affinity: Not known.

Genus Arcellites Miner (1935), emend. Potter (1963)

Arcellites mirabilis Kimyai, new species
Plate 1, figures 19–20

Description: Spore body triangular with sides convex and corners acute or slightly rounded; necklike segments fairly well developed; laesurae distinct, reaching to equator of spore body; exine two-layered; endexine 1–2 μ thick; ectexine 2–4 μ thick; body wall granulate. Over-all length, including segments, 100–110 μ; diameter of central body 40–65 μ.

Holotype: OPC 989 M–4–3. Dimensions 60.0 × 100.0 μ.

Remarks: This species is common in the Raritan Formation.

Affinity: Not known.

Arcellites caudatus Kimyai, **new species**
Plate 2, figures 1–2

Description: Spore body spherical, with a long twisted appendage; necklike segments present; laesurae indistinct; exine composed of two layers, ectexine 2–3 μ thick and endexine 1–1.5 μ thick; body wall granulate. Over-all length, including segments, 110–130 μ; diameter of central body 46–55 μ.

Holotype: OPC 989 G-3-2. Dimensions 80.0 × 117.0 μ.

Remarks: This species differs from *Arcellites nudus* (Cookson and Dettmann, 1958) Potter (1963) by having a long twisted appendage and not clearly showing six necklike segments. It is a common form in the Raritan Formation.

Affinity: Not known.

Class GYMNOSPERMAE
Order CYCADALES-BENNETTITALES
Genus MONOSULCITES Cookson (1947) ex Couper (1953)

Monosulcites scaber Kimyai, **new species**
Plate 2, figure 3

Description: Grain monosulcate; sulcus almost reaching ends of grain, usually gaping widely near the ends; exine psilate to scabrate, 1.5–2 μ thick. Size 35–43 × 49–57 μ.

Holotype: OPC 990 F-4-2. Dimensions 40.0 × 55.0 μ.

Remarks: This species is abundant in the Raritan Formation.

Affimity: With pollen of order Cycadales or order Bennettitales.

Order CONIFERALES
Family PINACEAE
Genus PINUSPOLLENITES Raatz (1937)

Pinuspollenites megasaccus Kimyai, **new species**
Plate 2, figure 4

Description: Bisaccate pollen; central body circular to oval in equatorial contour; proximal cap granulose, fairly well defined, 2–2.5 μ thick; exine of bladders merging into exine of proximal cap; bladders reticulate; mesh of reticulum 2–4 μ across; distal furrow 13 μ wide, lips of furrow more or less straight. Dimensions: Breadth of grain 107–118 μ, length of grain 61–72 μ, breadth of bladder 48–53 μ, length of bladder 40–46 μ, breadth of central body 69–80 μ, length of central body 55–60 μ.

Holotype: OPC 989 M-3-3. Over-all dimensions 67.0 × 112.0 μ.

Affinity: With pollen of the family Pinaceae and its modern genus *Pinus*.

Pinuspollenites granulatus Kimyai, **new species**
Plate 2, figure 5

Description: Bisaccate pollen; central body circular to oval in equatorial contour; proximal cap distinct, 2.5–3 μ thick; bladders broader than long, ornamented with verrucae; central body microreticulate to granulate; distinct notch between bladders and central body. Dimensions: Breadth of grain 71–79 μ, length of grain 40–50 μ, length of central body 18–23 μ, breadth of central body 43–52 μ, length of bladder 25–31 μ, breadth of bladder 32–37 μ.

Holotype: OPC 990 B-3-9. Over-all dimensions 45.0 × 75.0 μ.

Affinity: With pollen of the family Pinaceae, and its modern genus *Pinus*.

Genus PICEAEPOLLENITES Potonié (1931)

Piceaepollenites subconcinnus Kimyai, **new species**
Plate 2, figure 6

Description: Bisaccate pollen; central body circular to oval in equatorial contour; bladders small, almost the same size; no distinct notch between central body and bladders; both central body and bladders granulate to microreticulate; proximal cap granular, 2–3 μ thick. Dimensions: Length of central body 41–49 μ, length of bladder 20–30 μ, breadth of bladder 25–30 μ, breadth of central body 55–62 μ, total length of grain 42.0–53.5 μ.

Holotype: OPC 988 D-1-13. Over-all dimensions 47.5 × 60.0 μ.

Affinity: With pollen of the family Pinaceae and its modern genus *Picea*.

Genus TSUGAEPOLLENITES Potonié and Venitz (1934)

Tsugaepollenites insuetus Kimyai, **new species**
Plate 2, figure 9

Description: Inaperturate pollen; grain circular in equatorial contour; exine thick and verrucate. Equatorial diameter 59–90 μ.

Holotype: OPC 989 B-5-1. Dimensions 87.0 × 87.0 μ.

Remarks: This species with thick exine and verrucate ornamentation is similar to the form reported by Groot, Penny and Groot (1961) as *Tsugaepollenites* sp. from the undifferentiated Magothy-Raritan Formation.

Affinity: With pollen of the family Pinaceae and its modern genus *Tsuga*.

Genus PARVISACCITES Couper (1958)

Parvisaccites sphaericorpus Kimyai, **new species**
Plate 2, figure 7

Description: Bisaccate pollen; central body spherical; bladders attached distally, small in comparison to size of body, verrucose; verrucae 1–2 μ wide; distal furrow long, extending to ends of central body and becoming wider at ends; lips straight, 3–6 μ thick. Dimensions: Diameter of central body 39–47 μ, length of bladder 39–47 μ, breadth of bladder 23–25 μ.

Holotype: OPC 990 A–1–2. Over-all dimensions 43.0 × 43.0 μ.

Affinity: Possibly with pollen of the Coniferae.

Family PODOCARPACEAE?
Genus PLATYSACCUS Naumova (1937) ex Potonié and Klaus (1954)

Platysaccus radiatus Kimyai, **new species**
Plate 2, figure 8

Description: Bisaccate pollen; central body circular to elliptical in equatorial contour; grain broader than long; bladders large and attached to distal side of body near polar axis; bladders covering central body except in a narrow furrow between them across the distal pole; exine of central body smooth, thin; exine of bladders 1–2 μ thick, reticulate. Dimensions: Total breadth of grain 51–63 μ, total length of grain 37–46 μ, breadth of bladder 22–27 μ, breadth of central body 23–37 μ, length of central body 19–31 μ, breadth of distal furrow 5–8 μ.

Holotype: OPC 989 F–3–3. Over-all dimensions 40.0 × 58.0 μ.

Remarks: The central body covered with bladders and the narrow furrow on the distal side are outstanding features of this species.

Affinity: Possibly with pollen of the family Podocarpaceae.

Family CUPRESSACEAE
Genus INAPERTUROPOLLENITES Pflug (1952) ex Thomson and Pflug (1953), emend. Potonié (1958)

Inaperturopollenites tenuis Kimyai, **new species**
Plate 2, figure 10

Description: Inaperturate pollen; oval to irregular contour; grains strongly folded, frequently split; exine smooth, very thin, 0.5 μ thick. Equatorial diameter 30–35 μ.

Holotype: OPC 990 L–1–1. Dimensions 30.0 × 30.0 μ.

Remarks: This frequently ruptured grain is an extremely abundant form in the Raritan Formation and seems to have no stratigraphic significance.

Affinity: With pollen of the order Coniferales, probably of the family Cupressaceae.

CONIFERALES INCERTAE SEDIS

Genus **Naviculaformipites** Kimyai, **new genus**

Diagnosis: Bisaccate pollen; oval in polar view; central body longitudinally striate on proximal face, the striation consisting of 8–12 ridges with equal width; ridges 2–2.5 μ thick; interridge areas 1.5–3 μ wide.

Type species: Naviculaformipites atlanticus Kimyai, n. sp.

Remarks: This form was assigned to the genus *Vittatina* by Pocock (1962), but, in the writer's opinion, the Mesozoic forms similar to *Vittatina* should be transferred to the new Mesozoic genus *Naviculaformipites*.

Naviculaformipites atlanticus Kimyai, **new species**
Plate 2, figure 11

Description: Bisaccate pollen; oval in polar view with irregular outline; central body longitudinally striate on proximal face; striation consisting of 8–10 ridges of equal width; ridges 2–2.5 μ thick; interridge areas 2–3 μ wide; exine of both central body and bladders reticulate. Dimensions: Length of central body 29–35 μ, breadth of central body 41–56 μ, length of bladder 29–38 μ, breadth of bladder 20–27 μ, total length of grain 30–38 μ, total breadth of grain 95–104 μ.

Holotype: OPC 990 C–3–2. Dimensions 35.0 × 94.0 μ.

Remarks: This species differs from *Naviculaformipites psilatus* by having an irregular outline and a reticulate exine.

Affinity: With pollen of the order Coniferales.

Naviculaformipites psilatus Kimyai, **new species**
Plate 2, figure 12

Description: Bisaccate pollen; oval in polar view; central body longitudinally striate on proximal face; striation consisting of 8–12 ridges of equal width; ridges 2–2.5 μ thick; interridge areas 1.5–2 μ wide; striation continuing into inner part of bladders on proximal side; outer part of bladders either smooth or segmented. Dimensions: Length of central body 39–40 μ, breadth of central body 52–68 μ, length of bladder 41–58 μ, breadth of bladder 15–22 μ, total length of grain 39–48 μ, total breadth of grain 80–100 μ.

Holotype: OPC 990 B–4–2. Dimensions 45.0 × 90.0 μ.

Affinity: With pollen of the order Coniferales.

Class ANGIOSPERMAE
Family PALMAE
Genus SABALPOLLENITES Thiergart (1938)

Sabalpollenites dividuus Kimyai, **new species**
Plate 2, figure 13

Description: Monocolpate pollen grain; bilateral, spherical; colpus broad, 2–5 μ wide, extending almost to the equator, 26–27 μ long; lips of furrow 2–3 μ thick; exine

1.5–2 μ thick, finely reticulate; mesh of reticulum 1–1.5 μ across. Equatorial diameter 34–39 μ.

Holotype: OPC 990 F–2–17. Equatorial diameter 37.0 μ.

Remarks: This species is morphologically similar to *Rectosulcites latus* (Anderson, 1960) from the Cretaceous-Tertiary of New Mexico, but differs in having a reticulate exine.

Affinity: Probably with pollen of the modern palm genus *Sabal.*

Family PROTEACEAE
Genus PROTEACIDITES Cookson (1950)

Proteacidites rectilatus Kimyai, **new species**
Plate 2, figure 14

Description: Triporate pollen grain; equatorial contour triangular; pores almost circular, closed or slightly open; exine coarsely reticulate, 0.5–1 μ thick, becoming thicker in pore areas, mesh of reticulum 1–2 μ across. Equatorial diameter 23–28 μ.

Holotype: OPC 990 H–4–4. Equatorial diameter 25.0 μ.

Affinity: Probably with pollen of the family Proteaceae.

DICOTYLEDONES INCERTAE SEDIS
Genus CONCLAVIPOLLIS Pflug (1953)

Conclavipollis densilatus Kimyai, **new species**
Plate 2, figure 15

Description: Triporate pollen grain; aspidate; pores with more or less wide opening; equatorial contour triangular with concave sides; often well-developed exinal thickening on sides; exine almost psilate to slightly scabrate, 1.5–2 μ thick. Equatorial diameter 23–36 μ.

Holotype: OPC 990 A–3–4. Equatorial diameter 30.0 μ.

Affinity: Not known.

Genus TRICOLPITES Cookson (1947) ex Couper (1953)

Tricolpites heusseri Kimyai, **new species**
Plate 2, figure 16

Description: Tricolpate pollen grain; subrounded in equatorial contour; colpi broad, reaching to the pole, narrowing at pole; exine 1.5–2 μ thick, reticulate; mesh of reticulum 0.5–1 μ. Equatorial diameter 23–25 μ.

Holotype: OPC 989 F–5–1. Equatorial diameter 23.0 μ.

Affinity: Unknown.

Tricolpites balmei Kimyai, **new species**
Plate 2, figure 17

Description: Tricolpate pollen grain; subspherical; in polar view colpi gaping, reaching one-half of radius of grain; exine thick, 3–3.5 μ, openly reticulate; lumina 2–3 μ wide; muri 1–2 μ thick. Equatorial diameter 39–47 μ.

Holotype: OPC 990 K–5–1. Equatorial diameter 45.0 μ.

Affinity: Unknown.

Tricolpites wilsonii Kimyai, **new species**
Plate 2, figure 18

Description: Tricolpate pollen grain; subcircular in equatorial contour, with slightly convex sides; colpi extending almost to the poles; trilobate outline in polar view; exine 1–1.5 μ thick, reticulate; mesh of reticulum 0.5–1.5 μ across. Equatorial diameter 35–39 μ.

Holotype: OPC 990 H–3–2. Equatorial diameter 38.0 μ.

Affinity: Unknown.

MARINE MICROFOSSILS
Genus HYSTRICHOSPHAERIDIUM Deflandre (1937)

Hystrichosphaeridium raritanianum Kimyai, **new species**
Plate 2, figure 19

Description: Body almost circular in equatorial contour, laevigate; appendages 4–6 μ long, 3–6 μ wide, variable in shape; tips of appendages irregularly bifurcate; number of appendages 8–12. Equatorial diameter 39–46 μ.

Holotype: OPC 990 G–4–4. Equatorial diameter 42.0 μ.

Remarks: This form differs from *Hystrichosphaeridium tubiferum* (Ehrenberg, 1838) Deflandre (1937) by its short, wide appendages and larger central body. It is common in the Raritan Formation.

Hystrichosphaeridium multicornutum Kimyai,
new species
Plate 2, figure 20

Description: Body globular to cylindrical; poles not well rounded; body bearing 30–40 thin appendages; appendages 10–15 μ in length, almost perpendicular to the body surface, wide at the base, gradually tapering to the tips. Equatorial diameter 60–85 μ.

Holotype: OPC 989 P–2–1. Equatorial diameter 60.0 μ.

Remarks: This form is similar to *Hystrichosphaeridium xanthiopyxides* Deflandre (1937), but has more appendages.

Genus OODNADATTIA Eisenack and Cookson (1960)

Oodnadattia cooksonii Kimyai, **new species**
Plate 2, figure 21

Description: Shell longer than broad; apical and antapical surfaces convex; shell circular to broadly oval in equatorial outline, with longitudinal furrow, bordered with two membranous wings; outer wing 8–10 μ and inner one 12–14 μ wide; intermediate plates extending into the equatorial wing. Diameter 63–75 μ.

Holotype: OPC 989 Q–3–1. Diameter 63–75 μ.

Remarks: A few specimens of this species were found in the Raritan Formation.

REFERENCES

ANDERSON, R. Y.
1960 – *Cretaceous-Tertiary palynology, eastern side of the San Juan Basin, New Mexico.* New Mexico, Bur. Mines Min. Res., Mem., no. 6, pp. 1–58, pls. 1–11.

BALME, B. E.
1957 – *Spores and pollen grains from the Mesozoic of Western Australia.* Commonwealth Sci. Ind. Res. Org., Coal Res. Sect., Reference T. C. 25, pp. 1–48, pls. 1–11.

BERRY, E. W.
1911 – *The flora of the Raritan Formation.* New Jersey, Geol. Survey, Bull., no. 3, pp. 1–233, pls. 1–29.

BOLKHOVITINA, N. A.
1953 – *Characteristics of the spores and pollen of the Cretaceous deposits of the central regions of the* USSR. Acad. Sci. USSR, Inst. Geol. Sci., Trans., no. 145, (Geol. Ser. no. 61), pp. 1–183, pls. 1–16, [Russian].

BRENNER, G. J.
1963 – *The spores and pollen of the Potomac Group of Maryland.* Maryland, Dept. Geol., Mines and Water Res., Bull., no. 27, pp. 1–215, pls. 1–43.

CLARK, W. B.
1893 – *Cretaceous and Tertiary geology – Report of progress.* New Jersey, Geol. Survey, Ann. Rept. State Geol. for 1893, pp. 333–355.

COOKSON, ISABEL C.
1947 – *Plant microfossils from the lignites of Kerguelen Archipelago.* B. A. N. Z. Antarctic Res. Exped., 1929–1931, Repts., ser. A, vol. 2, pt. 8, pp. 127–142, pls. 13–17.

COOKSON, ISABEL C., and DETTMANN, MARY E.
1958 – *Cretaceous "megaspores" and a closely associated microspore from the Australian region.* Micropaleontology, vol. 4, no. 1, pp. 39–49, pls. 1–2.
1959 – *On Schizosporis, a new form genus from Australian Cretaceous deposits.* Micropaleontology, vol. 5, no. 2, pp. 213–216, pl. 1.

PLATE 1

1 *Cingulatisporites carinatus* Kimyai, n. sp.
Diameter 50.0 μ, OPC 990 G–3–5.

2 *Cingulatisporites exiniconfertus* Kimyai, n. sp.
Diameter 27.0 μ, OPC 990 C–2–17.

3 *Cingulatisporites pyriformis* Kimyai, n. sp.
Diameter 40.0 μ, OPC 989 F–4–3.

4 *Appendicisporites multicornutus* Kimyai, n. sp.
Diameter 67.0 μ, OPC 990 C–5–5.

5–6 *Cicatricosisporites verrucosus* Kimyai, n. sp.
5, diameter 50.0 μ, OPC 990 H–2–1;
6, diameter 57.0 μ, OPC 990 D–7–1.

7 *Gleicheniidites raritanianus* Kimyai, n. sp.
Diameter 30.0 μ, OPC 990 G–2–8.

8 *Gleicheniidites orientalis* (Bolkhovitina, 1953) Kimyai, n. comb.
Diameter 35.0 μ, OPC 990 A–5–4.

9 *Matonisporites globosus* Kimyai, n. sp.
Diameter 55.0 μ, OPC 990 C–1–2.

10 *Concavisporites granulatus* Kimyai, n. sp.
Diameter 35.0 μ, OPC 990 A–4–1.

11 *Concavisporites tricornutus* Kimyai, n. sp.
Diameter 44.0 μ, OPC 989 F–5–5.

12 *Concavisporites orbicornutus* Kimyai, n. sp.
Diameter 52.0 μ, OPC 989 J–1–3.

13 *Deltoidospora incomposita* Kimyai, n. sp.
Diameter 25.0 μ, OPC 990 J–5–5.

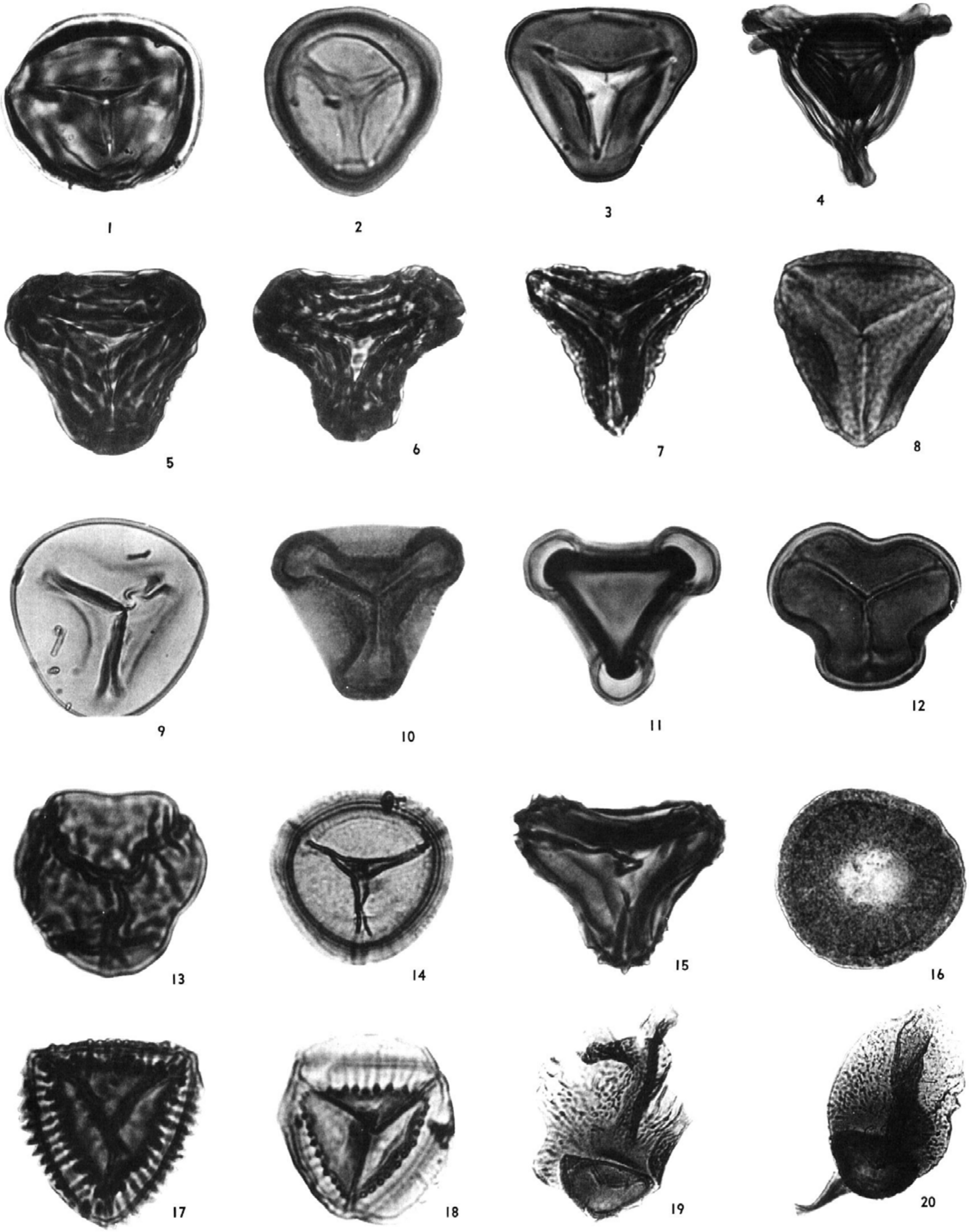
14 *Aequitriradites insolitus* Kimyai, n. sp.
Diameter 40.0 μ, OPC 989 P–1–1.

15 *Pilosisporites papilloides* Kimyai, n. sp.
Diameter 37.0 μ, OPC 989 F–3–2.

16 *Discisporites discoides* Kimyai, n. sp.
Diameter 50.0 μ, OPC 990 L–4–5.

17–18 *Wilsonisporites woodbridgei* Kimyai, n. sp.
17, diameter 42.0 μ, OPC 990 F–4–1;
18, diameter 43.0 μ, OPC 990 C–4–6.

19–20 *Arcellites mirabilis* Kimyai, n. sp.
19, 60.0 × 100.0 μ, OPC 989 M–4–3;
20, 43.0 × 105.0 μ, OPC 989 M–4–1.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COUPER, R. A.
1953 – *Upper Mesozoic and Cainozoic spores and pollen grains from New Zealand*. New Zealand, Geol. Survey, Pal. Bull., no. 22, pp. 1–77, pls. 1–9.
1958 – *British Mesozoic microspores and pollen grains*. Palaeontographica, Abt. B, vol. 103, nos. 4–6, pp. 75–179, pls. 15–31.

DEFLANDRE, G.
1937 – *Microfossiles des silex crétacés. Deuxième partie. Flagellés incertae sedis, Hystrichosphaeridés, Sarcodinés, organismes divers*. Ann. Pal., vol. 26, pp. 51–103, pls. 11–18.

DELCOURT, A., and SPRUMONT, G.
1955 – *Les spores et les grains de pollen du Wealdien du Hainaut*. Soc. Belge Géol., Mém., n. ser., quarto, no. 5, pp. 1–73, pls. 1–4, text-figs. 1–15.

DORF, E.
1952 – *Critical analysis of Cretaceous stratigraphy and paleobotany of Atlantic Coastal Plain*. Amer. Assoc. Petr. Geol., Bull., vol. 36, no. 11, pp. 2161–2184.

GROOT, J. J., and GROOT, C. R.
1962 – *Some plant microfossils from the Brightseat Formation (Paleocene) of Maryland*. Palaeontographica, Abt. B, vol. 111, nos. 4–6, pp. 161–171, 3 pls.

GROOT, J. J., and PENNY, J. S.
1960 – *Plant microfossils and age of nonmarine Cretaceous sediments of Maryland and Delaware*. Micropaleontology, vol. 6, no. 2, p. 225–236, pls. 1–2.

GROOT, J. J., PENNY, J. S., and GROOT, C. R.
1961 – *Plant microfossils and age of the Raritan, Tuscaloosa, and Magothy Formations of the eastern United States*. Palaeontographica, Abt. B, vol. 108, nos. 3–6, pp. 121–140, pls. 24–26.

PLATE 2

1–2 *Arcellites caudatus* Kimyai, n. sp.
1, 80.0 × 117.0 μ, OPC 989 G–3–2;
2, 55.0 × 115.0 μ, OPC 989 N–3–2.

3 *Monosulcites scaber* Kimyai, n. sp.
40.0 × 55.0 μ, OPC 990 F–4–2.

4 *Pinuspollenites megasaccus* Kimyai, n. sp.
67.0 × 112.0 μ, OPC 989 M–3–3.

5 *Pinuspollenites granulatus* Kimyai, n. sp.
45.0 × 75.0 μ, OPC 990 B–3–9.

6 *Piceaepollenites subconcinnus* Kimyai, n. sp.
47.0 × 60.0 μ, OPC 988 D–1–13.

7 *Parvisaccites sphaericorpus* Kimyai, n. sp.
Diameter 43.0 μ, OPC 990 A–1–2.

8 *Platysaccus radiatus* Kimyai, n. sp.
40.0 × 58.0 μ, OPC 989 F–3–3.

9 *Tsugaepollenites insuetus* Kimyai, n. sp.
Diameter 87.0 μ, OPC 989 B–5–1.

10 *Inaperturopollenites tenuis* Kimyai, n. sp.
30.0 × 35.0 μ, OPC 990 L–1–1.

11 *Naviculaformipites atlanticus* Kimyai, n. sp.
35.0 × 93.0 μ, OPC 990 C–3–2.

12 *Naviculaformipites psilatus* Kimyai, n. sp.
45.0 × 90.0 μ, OPC 990 B–4–2.

13 *Sabalpollenites dividuus* Kimyai, n. sp.
Diameter 37.0 μ, OPC 990 F–2–17.

14 *Proteacidites rectilatus* Kimyai, n. sp.
Diameter 25.0 μ, OPC 990 H–4–4.

15 *Conclavipollis densilatus* Kimyai, n. sp.
Diameter 30.0 μ, OPC 990 A–3–4.

16 *Tricolpites heusseri* Kimyai, n. sp.
Diameter 23.0 μ, OPC 989 F–5–1.

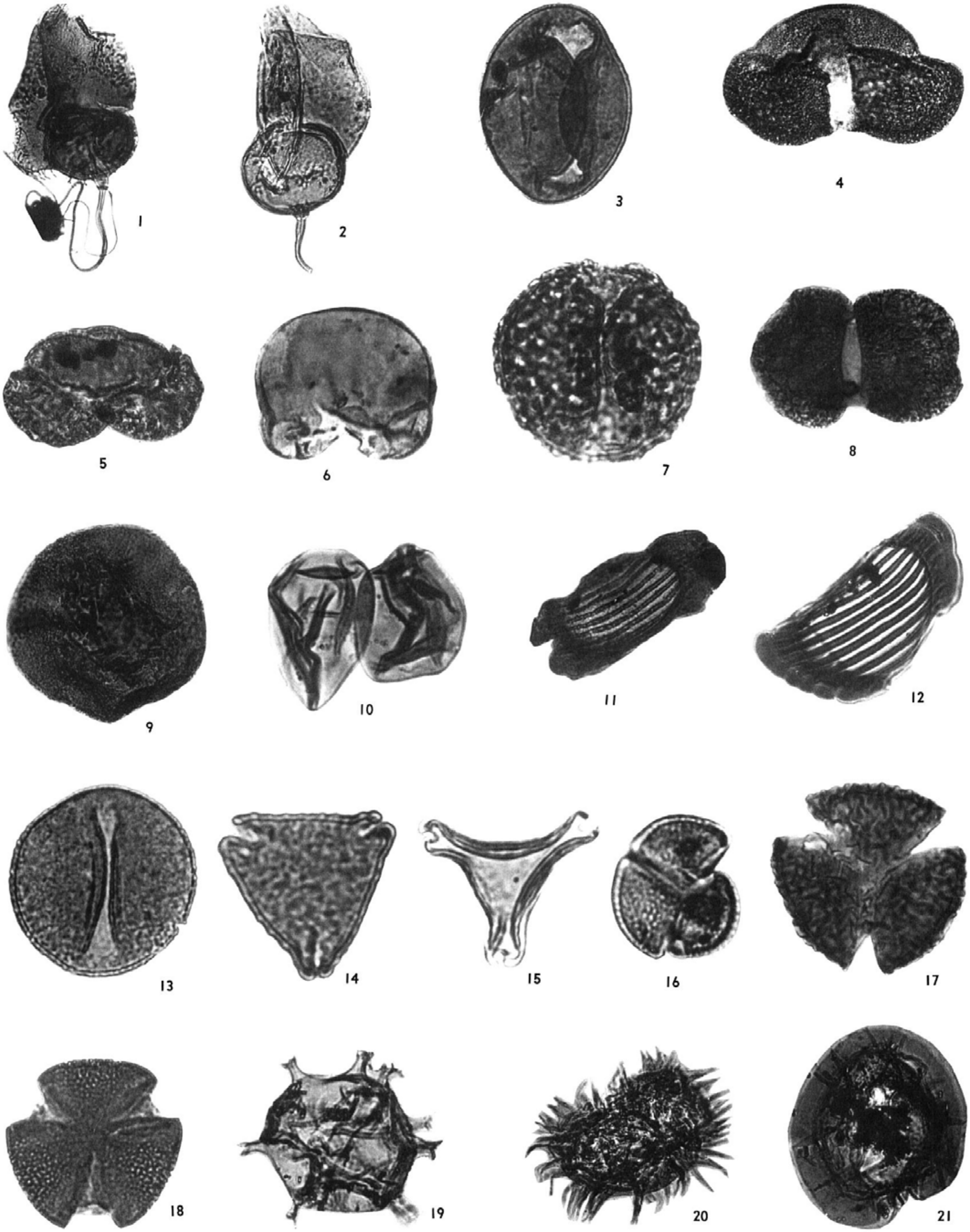
17 *Tricolpites balmei* Kimyai, n. sp.
Diameter 45.0 μ, OPC 990 K–5–1.

18 *Tricolpites wilsonii* Kimyai, n. sp.
Diameter 38.0 μ, OPC 990 H–3–2.

19 *Hystrichosphaeridium raritanianum* Kimyai, n. sp.
Diameter 42.0 μ, OPC 990 G–4–4.

20 *Hystrichosphaeridium multicornutum* Kimyai, n. sp.
60.0 × 85.0 μ, OPC 989 P–2–1.

21 *Oodnadattia cooksonii* Kimyai, n. sp.
63.0 × 73.0 μ, OPC 989 Q–3–1.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KÜMMEL, H. B., and KNAPP, G. N.
1904 – *The stratigraphy of the New Jersey clays.* New Jersey, Geol. Survey, Final Rept., vol. 6, pp. 117–209.

MINER, E. L.
1935 – *Paleobotanical examinations of Cretaceous and Tertiary coals.* Amer. Midland Nat., vol. 16, no. 4, pp. 585–625, pls. 18–24, text-figs. 1–6.

NEWBERRY, J. S.
1895 – *The flora of the Amboy Clays.* U. S. Geol. Survey, Monogr., vol. 26, pp. 1–260, pls. 1–58.

NILSSON, T.
1958 – *Über das Vorkommen eines mesozoischen Sapropelgesteins in Schonen.* Lund, Univ., Årsskr., ser. 2, vol. 54, no. 10, pp. 1–111, pls. 1–8.

POCOCK, S. A. J.
1962 – *Microfloral analysis and age determination of strata at the Jurassic-Cretaceous boundary in the western Canada plains.* Palaeontographica, Abt. B, vol. 111, nos. 1–3, pp. 1–95, pls. 1–15, text-figs. 1–21.

POTONIÉ, R.
1956 – *Synopsis der Gattungen der sporae dispersae. I. Teil: Sporites.* Geol. Jahrb., Beih., no. 23, pp. 1–103, pls. 1–11.
1958 – *Synopsis der Gattungen der sporae dispersae. II. Teil: Sporites (Nachträge), Saccites, Aletes, Praecolpates, Polyplicates, Monocolpates.* Geol. Jahrb., Beih., no. 31, pp. 1–114, pls. 1–11.
1960 – *Synopsis der Gattungen der sporae dispersae. III. Teil: Sporites (Nachträge), Fortsetzung Pollenites mit Generalregister zu Teil I–III.* Geol. Jahrb., Beih., no. 39, pp. 1–189, pls. 1–9.

POTTER, D. R.
1963 – *An emendation of the sporomorph Arcellites Miner, 1935.* Oklahoma, Geol. Survey, Oklahoma Geol. Notes, vol. 23, no. 9, pp. 227–230, pl. 1.

RICHARDS, H. G.
1943 – *Fauna of the Raritan Formation of New Jersey.* Acad. Nat. Sci. Philadelphia, Proc., vol. 95, pp. 15–32.

ROSS, N.-E.
1953 – *On a Cretaceous pollen and spore bearing clay deposit of Scania.* Upsala, Univ., Geol. Inst., Bull., vol. 34, pp. 25–43, pls. 1–3, text-figs. 1–4.

ROUSE, G. E.
1959 – *Plant microfossils from Kootenay coal-measures strata of British Columbia.* Micropaleontology, vol. 5, no. 3, pp. 303–324, pls. 1–2.
1962 – *Plant microfossils from the Burrard Formation of western British Columbia.* Micropaleontology, vol. 8, no. 2, pp. 187–218, pls. 1–5.

SCHEMEL, M. P.
1950 – *Cretaceous plant microfossils from Iowa.* Amer. Jour. Bot., vol. 37, no. 9, pp. 750–754.

SPANGLER, W. B., and PETERSON, J. J.
1950 – *Geology of the Atlantic Coastal Plain in New Jersey, Delaware, Maryland, and Virginia.* Amer. Assoc. Petr. Geol., Bull., vol. 34, no. 1, pp. 1–100.

STEPHENSON, W. L.
1954 – *Additions to the faunas of the Raritan Formation (Cenomanian) of New Jersey.* U. S. Geol. Survey, Prof. Paper, no. 264–B.

THIERGART, F.
1949 – *Der stratigraphische Wert mesozoischer Pollen und Sporen.* Palaeontographica, Abt. B, vol. 89, pp. 1–34, pls. 1–5.

THOMSON, P. W., and PFLUG, H.
1953 – *Pollen und Sporen des mitteleuropäischen Tertiärs.* Palaeontographica, Abt. B, vol. 94, pp. 1–138, pls. 1–15, text-figs. 1–20.

WEYLAND, H., and GREIFELD, G.
1953 – *Über strukturbietende Blätter und pflanzliche Microfossilien aus den untersenonen Tonen der Gegend von Quedlinburg.* Palaeontographica, Abt. B, vol. 95, pp. 30–52, pls. 1–8, text-figs. 1–4.

WEYLAND, H., and KRIEGER, W.
1953 – *Die Sporen und Pollen der Aachener Kreide und ihre Bedeutung für die Charakterisierung des mittleren Senons.* Palaeontographica, Abt. B, vol. 95, pp. 6–29, pls. 1–5.

WILSON, L. R.
1959*a* *A method of determining a useful microfossil assemblage for correlation.* Oklahoma, Geol. Survey, Oklahoma Geol. Notes, vol. 19, no. 4, pp. 91–93, text-fig. 1.
1959*b* *A water miscible mountant for palynology.* Oklahoma Geol. Survey, Oklahoma Geol. Notes, vol. 19, no. 5, pp. 110–111.